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13. ABSTRACT (Maximum 200 words) This grant support from the Army Research Office (though 2004 DoD Instrumentation and Research Support Program for HBCU/MIs) has been used for acquisition of equipment to enhance nonlinear optics research and optics education programs at San Francisco State University (SFSU).  The primary objective of the proposed project is to study optically-induced photonic lattices and discrete-solitons based on partially incoherent light, and to explore the possibility of using discrete solitons as information carriers for soliton-based switching, routing, and navigation. Mother objective is to promote education and research of students at San Francisco State University, one of the national HBCU/MIs., in the fields of physical sciences and engineering.  As reported below, the work proposed in this project has been successfully completed, with more than 10 referred papers published during the project year which has credited ARO, and about a dozen students have participated in this project. Our work has been featured in Optics & Pho tonic News, Physics Today and Technology Research News.				
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## FINAL TECHNICAL REPORT

September 2005

### Equipment for Nonlinear Optics and Photonics Research

GRANT NO. W911NF-04-1-0366

Zhigang Chen

Department of Physics and Astronomy

San Francisco State University

zchen@stars.sfsu.edu

### Summary:

This grant support from the Army Research Office (though 2004 DoD Instrumentation and Research Support Program for HBCU/MIs) has been used for acquisition of equipment to enhance nonlinear optics research and optics education programs at San Francisco State University (SFSU). The primary objective of the proposed project is to study optically-induced photonic lattices and discrete-solitons based on partially incoherent light, and to explore the possibility of using discrete solitons as information carriers for soliton-based switching, routing, and navigation. Another objective is to promote education and research of students at San Francisco State University, one of the national HBCU/MIs., in the fields of physical sciences and engineering.

As reported below, the work proposed in this project has been successfully completed, with more than 10 referred papers published during the project year which has credited ARO, and about a dozen students have participated in this project. Our work has been featured in *Optics & Photonic News*, *Physics Today* and *Technology Research News*.

Specifically, we have made the following progress as proposed in the original proposal:

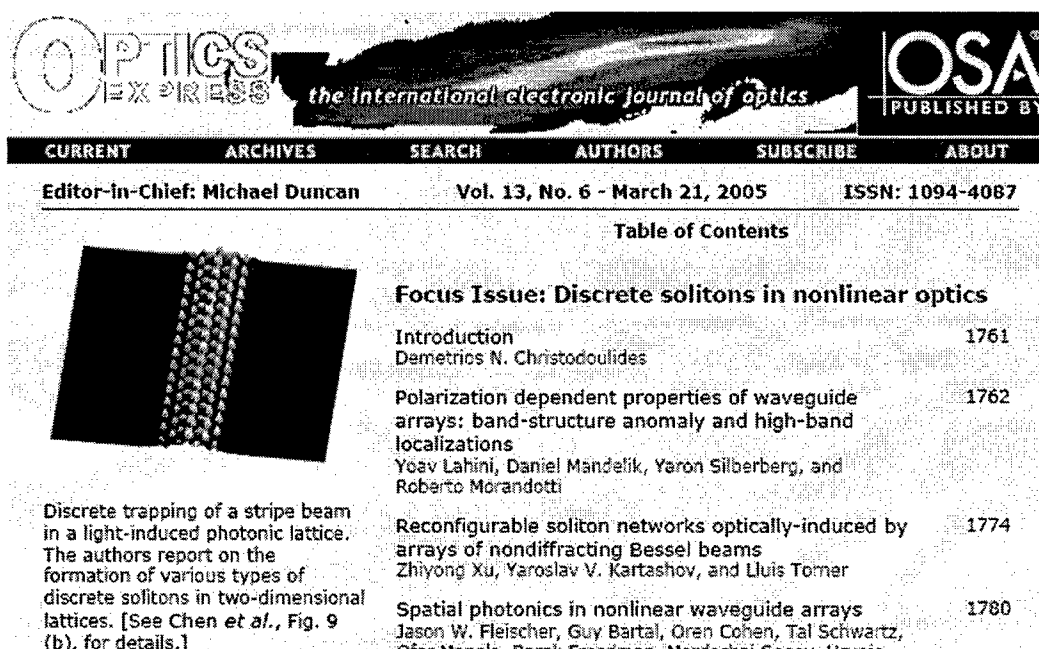
1. Developed a mathematical model along with a computational method for studying light-induced photonic lattices. Demonstrated two-dimensional photonic lattices optically induced in bulk nonlinear materials with partially incoherent light.
2. Studied light propagation in light-induced photonic lattices. Demonstrated intrinsic localized modes of various configurations in weakly-coupled waveguide lattices, including two-dimensional discrete solitons, discrete stripe solitons, and discrete vortex solitons. Obtained solutions for such soliton states by use of a continuous model with periodic potentials as well as a discrete model.
3. Studied nonlinear interaction between a soliton and a light-induced photonic lattice, and associated nonlinear phenomena including soliton-induced lattice dislocation, lattice deformation and compression, soliton dragging and routing, and signal propagation in discrete soliton network.
4. Explored potential applications of discrete solitons in all-optical devices and technology. Studied interactions and collisions between optical solitons embedded in photonic lattice structures for possible use in blocking, routing, and time-gating the transmission of intense laser signals.

## Major Effort and Accomplishments:

During the project year supported by the ARO grant, the P.I. has made significant progress in the research work as proposed in the original proposal. About 10 papers have already been published in premier physic, mathematics and optics journals including *Physical Review Letters*, *Stud. Appl. Math*, and *Optics Letters*. More manuscripts have been accepted or submitted for review. (See attached list of publications that have acknowledged the support from ARO). Below are some examples of our successful research work.

### 1. Discrete-soliton trains in a light-induced photonic lattice

We have demonstrated anisotropic enhancement of discrete diffraction and formation of two-dimensional discrete-soliton trains in a light-induced photonic lattice. Such discrete-soliton trains were realized under appropriate conditions due to discrete modulation instability of a one-dimensional stripe beam in a two-dimensional lattice optically-induced with partially incoherent light. We have developed a mathematical mode and corroborated experimental results by numerical simulations. This work has been featured in cover page of *Optics Express*, March 2005 (see below).



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Discrete trapping of a stripe beam in a light-induced photonic lattice. The authors report on the formation of various types of discrete solitons in two-dimensional lattices. [See Chen *et al.*, Fig. 9 (b), for details.]

## 2. High-order vortices and necklace structures in 2D photonic lattices

We have studied high-order vortices propagating in 2D photonic lattices using a continuous model with periodic lattice potentials as well as a discrete model. We have demonstrated the formation of stationary necklace-like solitons. Such ring soliton structures were realized when a high-order vortex beam was launched appropriately into a two-dimensional optically induced photonic lattice. Our theoretical results indicate that these necklace ring solitons are stable under certain conditions, in good agreement with experimental observations. This part of work has been included in two recent papers, one published in *Phys. Rev. E*, and the other in *Physical Review Letters*. This work is also featured in *Technology Research News* 2005 (see below).



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### System forms light necklace

The 1s and 0s of computer information are generally represented on computer chips by electrical signals. Using light signals instead promises to speed computing and more tightly integrate computers with optical communications lines.

Researchers from the University of Vermont, San Francisco State University, the University of Massachusetts at Amherst, Tel Aviv University in Israel, the University of Athens in Greece, and Nankai University in China who are working with soliton clusters have come a step closer to all-optical computing. A soliton is a sphere- or disk-shaped wave that does not spread out as it travels. The researchers have showed that it is possible to contain a lightwave as a soliton necklace -- a standing wave of light arranged as a ring of bright spots.

This type of lightwave control could eventually be used in micro-scale lightwave interference patterns, or photonic lattices, to carry out all-optical data processing, according to the researchers. In particular, the technique could be used to route light signals in all-optical communications devices and optoelectronic devices. The necklace soliton is also potentially useful as laser tweezers because it might have angular momentum that can be transferred to microparticles like cells.

To form a stable silicon necklace, the researchers shone a laser through a

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### Participation of underrepresented students in the proposed research

The P.I. has actively engaged students, especially underrepresented minorities, in his research. During the project year funded by ARO, a number of undergraduate and M.S. graduate students including woman and minority students have involved in the proposed research project.

### **Publications Acknowledged Support from ARO:**

(Asterisk indicates SFSU student co-authors)

1. P.G. Kevrekidis, B. A. Malomed, Z. Chen, and D.J. Frantzeskakis, "Stable higher charge vortices in the discrete nonlinear Schrodinger equation", *Phys. Rev. E*, **70**, 056612 (2004).
2. J. Yang, A. Bezryadina\*, I. Makasyuk, and Z. Chen, "Dipole and Quadripole solitons in optically-induced two-dimensional photonic lattices", *Stud. Appl. Math.* **113**, 389 (2004).
3. M. Asaro\*, M. Sheldon\*, J. Xu, Z. Chen, O. Ostroverkhova, W. E. Moerner, M. He and R. J. Twieg, "Soliton-induced waveguides in a photorefractive organic glass", accepted for publication in *Opt. Lett.* **30**, 519 (2005)
4. Z. Chen, H. Martin\*, E. D. Eugenieva, J. Xu, J. Yang, and D. N. Christodoulides, "Formation of discrete solitons in light-induced photonic lattices", focus issue in *Opt. Express*. (invited by feature editor), **13**, 1816 (2005).
5. Z. Chen, H. Martin\*, A. Bezryadina\*, D.N. Neshev, Y.S. Kivshar, D. N. Christodoulides, "Experiments on Gaussian beams and vortices in optically-induced photonic lattices", special issue in *J. Opt. Soc. Am. B*, (invited by feature editor) **22**, 1305-1405 (2005).
6. J. Yang, I. Makasyuk, H. Martin, P.G. Kevrekidis, B.A. Malomed, D.J. Frantzeskakis, and Z. Chen, "Necklace-like solitons in optically induced photonic lattices", *Phys. Rev. Lett.* **94**, 113902 (2005).
7. Z. Chen, J. Xu, C. Lou, "Novel Discrete Solitons in Light-induced Photonic Lattices", *Physics (Wuli)*, **34**, 12 (2005). (invited review article, in Chinese).
8. P.G. Kevrekidis, Z. Chen, B.A. Malomed, D.J. Frantzeskakis, and M.I. Weinstein. "Spontaneous Symmetry Breaking in Photonic Lattices as a Bifurcation Problem: Theory, Numerics and Experiment". *Phys. Lett. A*, **340**, 275-280 (2005).
9. Francesco Fedele, Jianke Yang, Z. Chen, "Defect Modes in One-dimensional Photonic Lattices", *Opt. Lett.* **30**, 1506-1509 (2005).
10. T. Kapitula, P.G. Kevrekidis, Z. Chen, "Three is a crowd: Solitary waves in photorefractive media with three potential wells", *SIAM Journal in Applied Dynamical Systems*, to appear (2005).
11. C. Lou, J. Xu, L. Tang, Z. Chen, P.G. Kevrekidis, "Symmetric and anti-symmetric solitons and Bloch states in optically induced lattices", *Opt. Lett.* submitted (2005).
12. X. Wang, Z. Chen and P.G. Kevrekidis, "Discrete solitons and soliton rotation in periodic ring lattices", *Phys. Rev. Lett.* submitted (2005).

## **Equipment acquired:**

INSTITUTION: San Francisco State University  
PROJECT DIRECTOR: Zhigang Chen  
TITLE: Equipment for Nonlinear Optics and Photonics Research  
SPONSOR: 2004 DoD Instrumentation and Research Support for HBCU/MIs

Equipment/Source	Cost
Solid State Laser Coherent Inc. Contact: Greg Losito (800) 400-3008	\$ 55,000
Beamview profiler and data acquisition systems Coherent Auburn Group	\$ 10,800
Optical Table and Air Compressor NewPort Corporation	\$ 10,900
Photorefractive crystal and optics Altechna Co. Ltd	\$ 7,500
Equipment Total	\$ 84,200

**This project has been successfully completed.  
The support from DoD is highly appreciated!**